

## Search for Gauge-Mediated SUSY Breaking in the Diphoton event with Large Missing $E_T$

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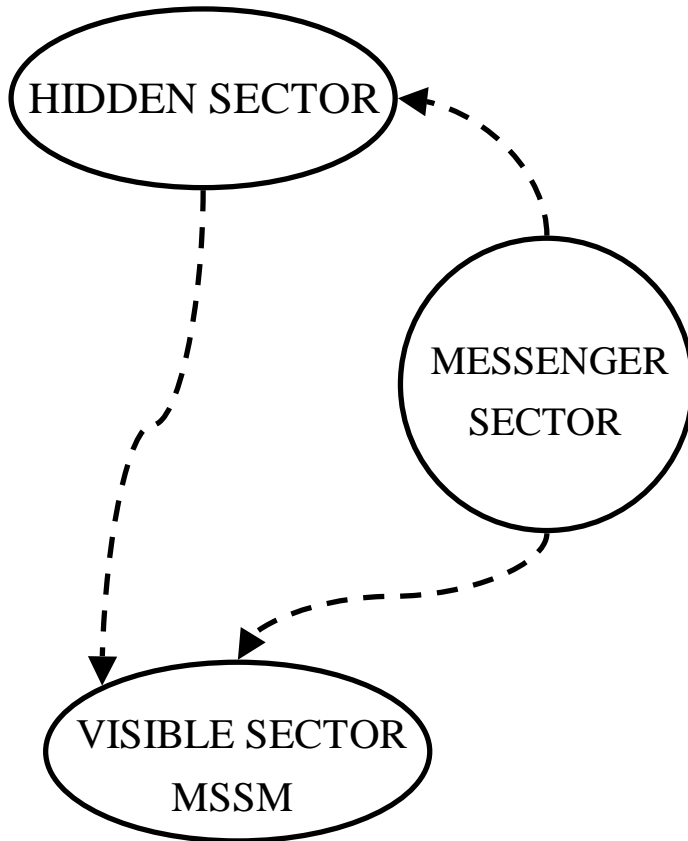
# Outline

- *Theory and Previous Experiments*
- *Data Analysis*
  - *Signal Event Selections*
  - *Backgrounds*
  - *Monte Carlo of SUSY Signal*
- *Signal Acceptances and Systematic Uncertainties*
- *Expected Mass Limit and Optimization*
- *Cross Section Limit @ 95% CL*
- *Conclusions*



# Gauge-Mediated SUSY Breaking

## SUSY Breaking Mechanism



- *Phenomenology*

- Gravitino: the Lightest SUSY Particle (LSP)
- Neutralino or Slepton: the NLSP

- *In case of Neutralino NLSP*

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}, \text{ BR} \sim 100\%$$

- *Signature*

- *two photons plus Missing  $E_T$  (MET)*
- *dominant processes:*

$$p\bar{p} \rightarrow \tilde{\chi}\tilde{\chi} \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 + X \rightarrow \gamma\gamma\tilde{G}\tilde{G} + X$$

“Sparticle Spectroscopy and Electroweak Symmetry Breaking with Gauge-Mediated Supersymmetry Breaking,” Nucl.Phys.B488,39-91

**Snowmass GMSB Model line, hep-ph/0201233**



# Previous Searches

- ***CDF has found an interesting event in Run I:  
 $ee\gamma\gamma E_T$  candidate***
- ***Mass Limits at 95% C.L. (GeV/c<sup>2</sup>)***

	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_1^0$
<b><i>CDF Run I</i></b>	120	65
<b><i>D0 Run I</i></b>	150	77
<b><i>LEP II</i></b>		99



# Signal Event Selections

- *Global Event Selections*
  - *Diphoton triggers in central*
  - $|Z_{\text{vertex}}| < 60$  cm
  - *Runs where the detector is working (202 pb<sup>-1</sup>)*
- *Standard Photon Identification and Isolation*
- *Remove cosmic ray which Bremsstrahlung or shower*
- *Remove event caused by Tevatron halo muons and/or beam-gas*
- *Additional cuts to remove MET mis-measurement*

*Two isolated central photons with  $E_T^\gamma > 13$  GeV  
⇒ diphoton candidate sample of 3,306 events*



# Backgrounds

- **QCD + Fake MET**
  - $\gamma\gamma, \gamma j \rightarrow \gamma_{fake}, jj \rightarrow \gamma_{fake}\gamma_{fake}$   
 $\Rightarrow \gamma\gamma: 29 \pm 4\%, \gamma j: 47 \pm 6\%, jj: 24 \pm 4\%$  (CES / CPR method)
  - *Drell-Yan with both electrons mis-ID as photons*
- **Electron faking photon with real or fake MET**
  - $W\gamma \rightarrow e\nu\gamma$  and  $Z\gamma \rightarrow ee\gamma$  (lost tracks)
  - $Wj \rightarrow evj$  (lost track and jet faking photon)
  - $Z \rightarrow \tau\tau \rightarrow ee\nu\nu\nu + X$  (lost tracks)
  - $t\bar{t} \rightarrow ee\nu\nu + X$  (lost tracks)
  - $WW, WZ, \text{etc.}$
- **Cosmics, beam halo, and beam-gas**



# QCD with Fake Missing $E_T$

- **The dominant background is QCD:  $\gamma\gamma$ ,  $\gamma j$  and  $jj$  where jet fakes photon, and MET is fake**
- **Estimate MET distribution from control sample of photon fakes, pass most but not all signal cuts (same MET response to signal)**
  - $\Rightarrow$  *diphoton control sample of 7,806 events*
- **Correct the MET distribution for:**
  - *e-gamma contamination (avoid double counting)*
  - *Difference in SumET distributions (differ by 6%)*
  - *Normalize to MET < 20 GeV from signal sample*
  - *Fit low-MET region to a double exponential to get Large MET prediction (systematic uncertainty from variation of selection cut and fit function)*



# e faking gamma background

- ***Electron with a lost track can fake a photon***
- ***Events with electrons can have real MET such as  $W\gamma \rightarrow e\nu$***
- ***Estimate all sources together ( $W\gamma$ ,  $Z\gamma$ ,  $t\bar{t}$ )***
  - *electron selection criteria: the normal cuts,  $0.8 < E/p < 1.2$ , using unbiased Z legs, and fitting to the Z peak:*
  - ***e-gamma signal sample of 462 events***  
*: added after multiplying by fake-rate<sup>1)</sup>*
  - *e-gamma control sample of 355 events*  
*: subtracted from control sample after multiplying by fake-rate<sup>2)</sup>*

$$\text{fake rate} = \frac{P_{recon}(e \rightarrow \gamma)}{P_{recon}(e \rightarrow e)} \quad \begin{array}{l} 1) 1.1 \pm 0.4\% \text{ for one leg passing tight photon cut} \\ 2) 2.8 \pm 0.5\% \text{ for one leg passing loose-but-not tight cut} \end{array}$$



# Cosmic/Halo/Beam-gas background (Remaining after all cuts)

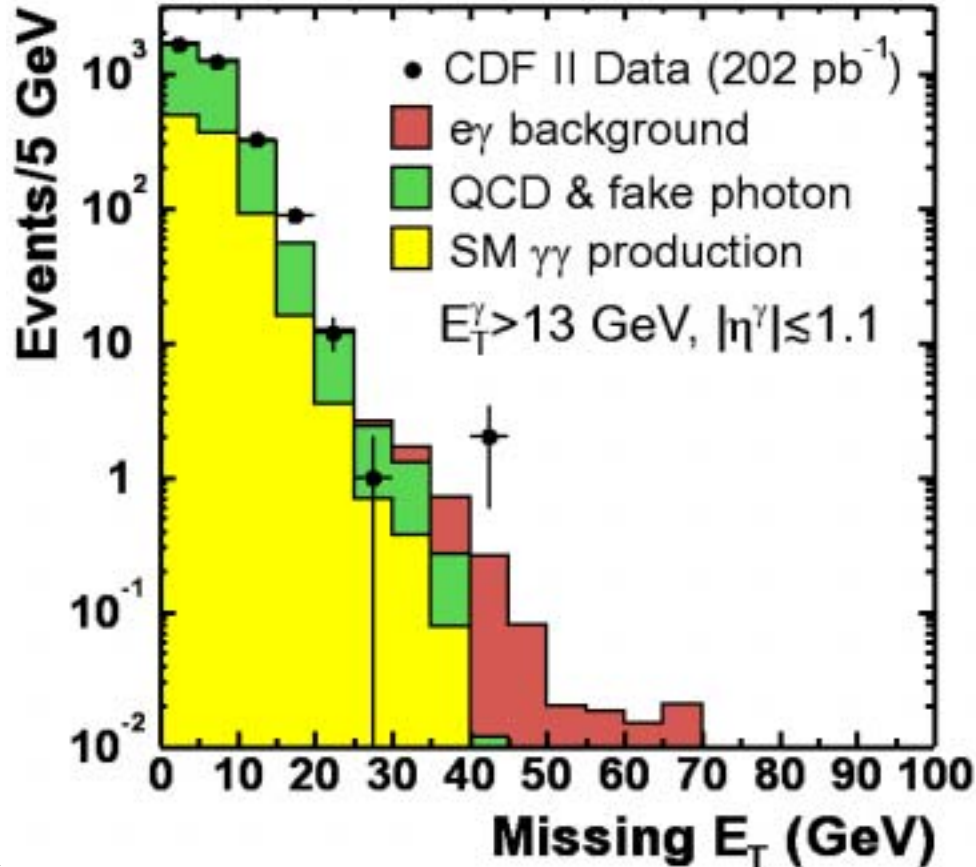
- **Three types:**
  - 1) *source causes one photon*
  - 2) *source causes both photons*
  - 3) *source causes other energy in the event, unrelated to photons*
- **Ways to Reject:**
  - *Photon(s) opposite MET and same magnitude of MET*
  - *Tevatron Beam halo rejection:*  
*(longitudinal energy deposits, wall calorimeter MIPs, efficiency=97%, rejection=good, CDF Note 6009)*
  - *Out-Of-Time energy from Hardron TDC*
- **Expected 0.12 events for  $MET > 45$  GeV**



# Missing $E_T$ Spectrum

- *0 events observed with  $MET > 45$  GeV*
- *The expected numbers of background events for  $MET > 45$  GeV*

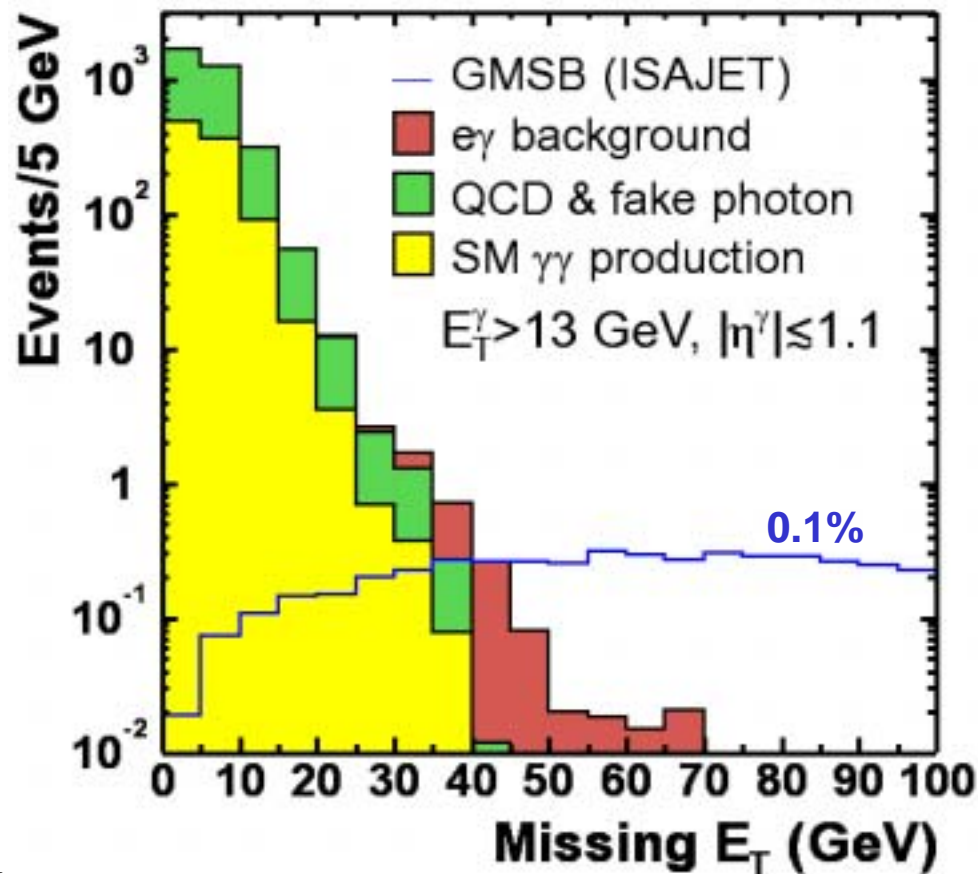
QCD and SM $\gamma\gamma$	$e$ faking $\gamma$	cosmic	Total
$0.01 \pm 0.01 \pm 0.01$	$0.14 \pm 0.06 \pm 0.05$	$0.12 \pm 0.03 \pm 0.09$	$0.27 \pm 0.07 \pm 0.10$





# SUSY Signal Monte Carlo

- *Estimate Acceptance with ISAJET and Detector simulation*
- *Correct for differences between MC and detector performance*

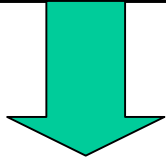




# Signal Acceptances

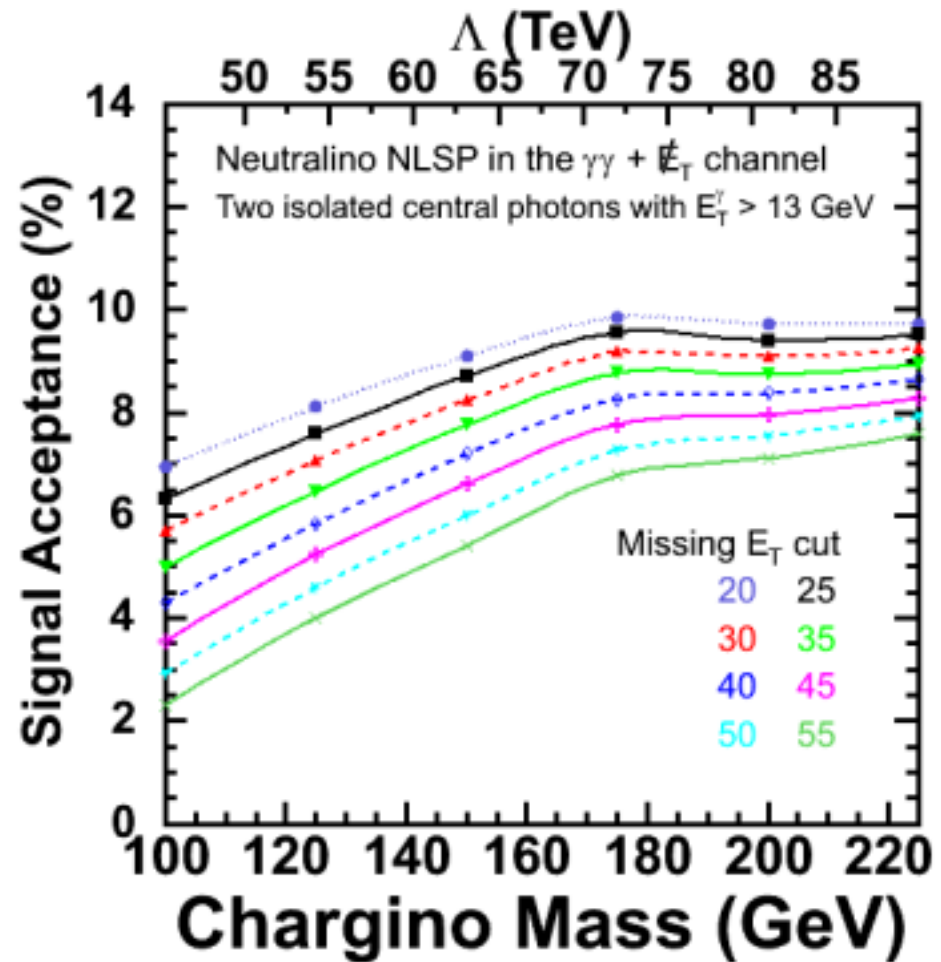
- Efficiency Corrections**

	Correction to MC
Z Study per photon	-3.50%
Conversion per pho	-3.70%
Vertex	-1.7%
Trigger	-0.3%



$$0.930 \times 0.926 \times 0.983 \times 0.997 = 0.841$$

<b>Total correction</b>	<b>-16%</b>
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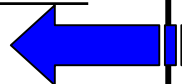


# Systematic Uncertainties

	Systematic uncertainty (%)	
Luminosity	6	
Monte Carlo statistics	1	
Cut efficiency	13	
ISR/FSR	10	
Q <sup>2</sup>	3	
PDFLIB (MRST98 LO)	+1	-5
	+17.8	-18.4
<b>Total</b>	<b>18%</b>	

Background uncertainties	
e-gamma	32%
control sample	
1) selection cuts	60%
2) fit variations	70%

Variable	Relative Syst. Uncertainty (%)
Had/Em	1.0
Cone 0.4 IsoEtCorr	5.0
Chi2 (Strip+Wires)/2	2.0
N track (N3D)	0.5
Track Pt	1.0
Cone 0.4 Track Iso	1.0
Fiducial	3.0
Conversions	1.2
Total per photon	6.5%
<b>Total per diphoton</b>	<b>13%</b>

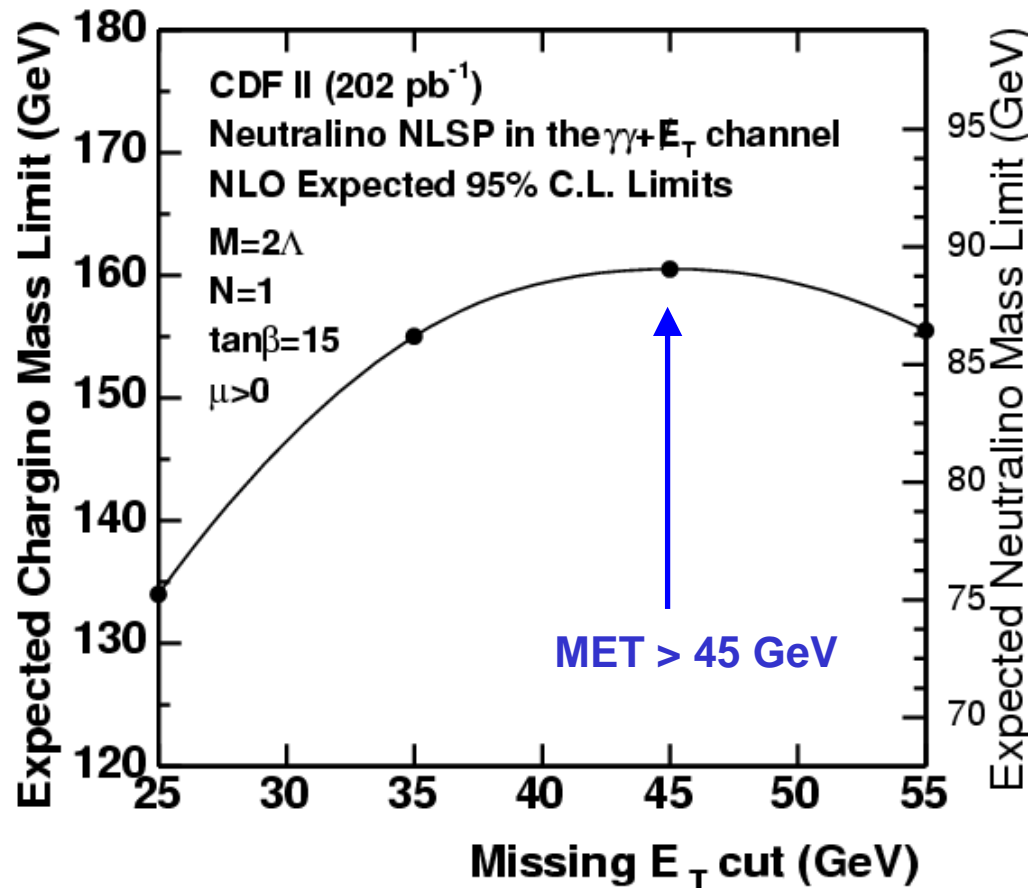




# Expected Limit vs. MET cut

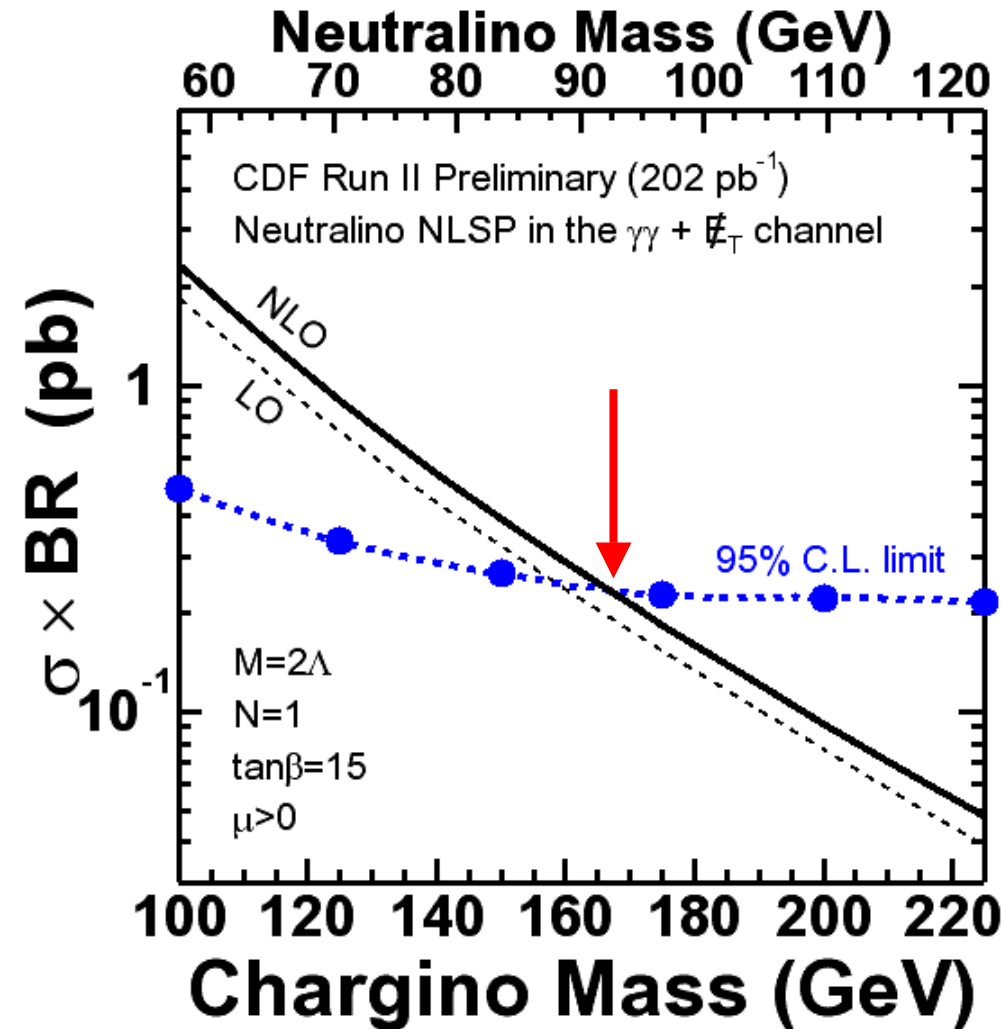
*From Data: Two isolated central photons with  $E_T > 13$  GeV*

*- Cuts( $E_T$ , MET clean-up, and MET) have been checked for optimization*





# Cross Section Limit @ 95% C.L.



- 0 events observed with  $E_T > 45$  GeV
  - $0.27 \pm 0.07(\text{stat.}) \pm 0.10(\text{syst.})$  expected
  - 18% systematic uncertainty on  $\varepsilon \times \mathcal{L}$
- $\Rightarrow N_{95\% \text{ C.L.}}$  limit of 3.3 events

- ***NLO Limit at 95% C.L.***

$$m(\tilde{\chi}_1^\pm) > 167 \text{ GeV}/c^2$$

$$m(\tilde{\chi}_1^0) > 93 \text{ GeV}/c^2$$

“The Production of Charginos/Neutralinos and Sleptons at Hardron Colliders,”  
PRL.83 (1999), 3780-3783

T.Plehn and M.Klasen *et.al.*



# Conclusions

- *We have searched for isolated high  $E_T$  diphoton events with large MET using data corresponding 202 pb<sup>-1</sup> (CDF Notes: 6310, 6317, and 6389)*
- *For  $MET > 45$  GeV, 0 events observed with  $0.27 \pm 0.07(\text{stat.}) \pm 0.10(\text{syst.})$  events expected*
- *Set a lower mass limit in GMSB (NLO) with 18% systematic uncertainty at 95% C.L.  
 $m(\tilde{\chi}_1^\pm) > 167 \text{ GeV}/c^2$  and  $m(\tilde{\chi}_1^0) > 93 \text{ GeV}/c^2$*
- *GP committee: Henry (chair), Jane, and Giulia  
<http://www-cdf.fnal.gov/internal/physics/GMSBDiPho>*
- *Paper draft in progress*